United States
Department of
Agriculture

Forest Service

Rocky Mountain
Forest and Range
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Fort Collins,
Colorado 80526

Research Paper
RM-304

Analysis of Standards and Guidelines in a Geographic Information System Using Existing Resource Data

Terry L. Gokee
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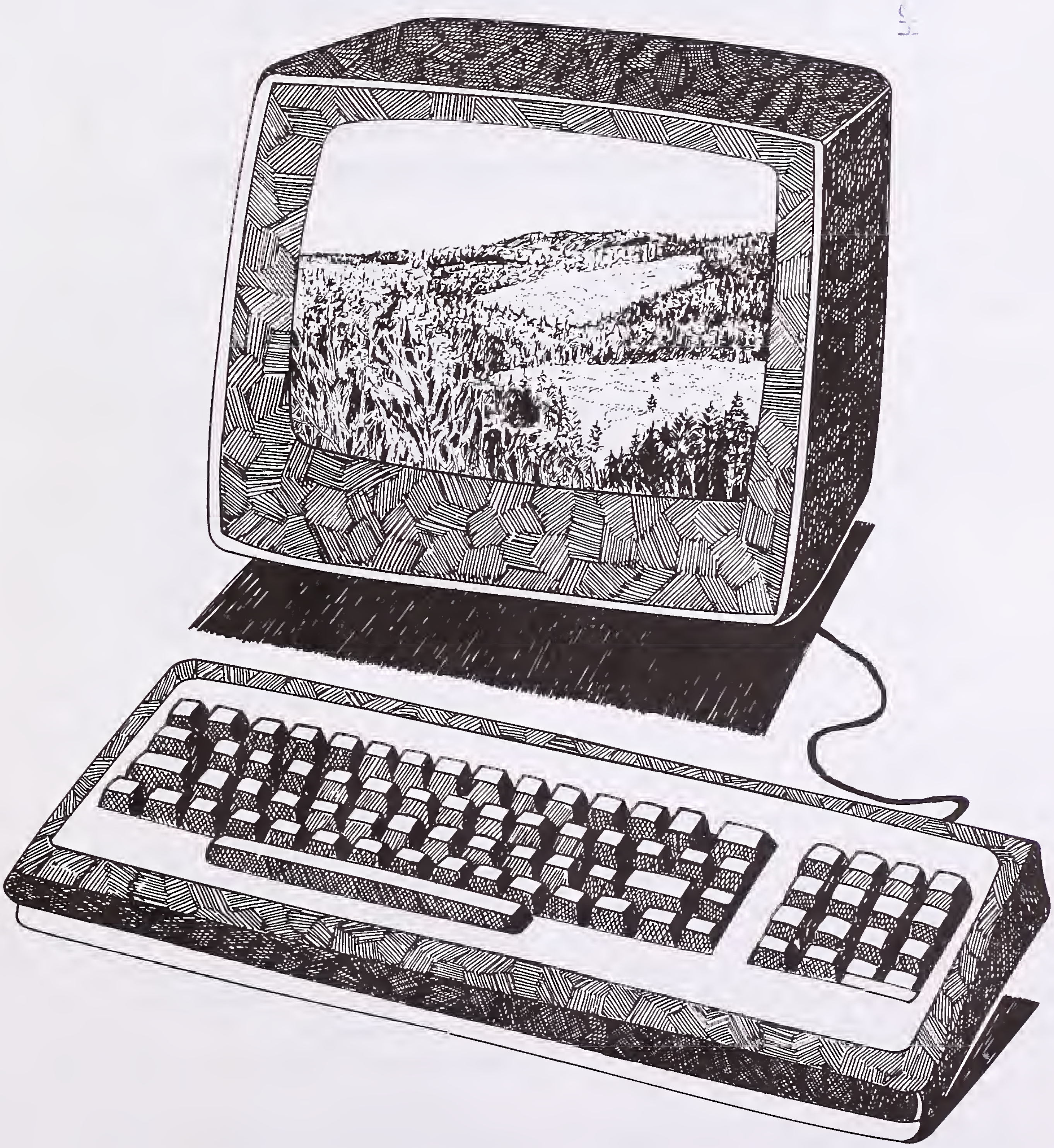

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October 1992

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Abstract

Using data from the Hayden Ranger District, Medicine Bow National Forest, methods for analyzing spatially explicit standards and guidelines within a geographic information system were developed. Only 19% of the standards and guidelines were described in a spatially explicit manner. Methods were developed for buffer analyses, neighbor analyses, Patton edge index analyses, and geographic distribution analyses. The low number of spatially explicit standards and guidelines indicates there is a need to begin thinking in spatial terms in resource management.

[1] *Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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INTRODUCTION

The U.S. Forest Service is required by the Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976 to develop land and resource management plans which guide resource management activities and establish management standards and guidelines. The forest plan utilizes an interdisciplinary approach to achieve integrated resource management for a balanced use of National Forest System lands. A forest plan is typically broken down into four sections:

1. INTRODUCTION. This section describes the forest plan, and the location of the forest.

2. MANAGEMENT SITUATION. This section describes the physical and biological environment of the forest. Plans usually break this description into resource areas or problem statements. This section is further divided into sections describing these resource areas for the present condition and for the desired future condition.

3. MANAGEMENT DIRECTION. This section describes how management will be implemented. Specifically, it contains goal statements for each resource area, objectives for outputs from each resource area, and management requirements that describe how specific management activities will be implemented.

4. MONITORING AND EVALUATION. This section lists techniques that will be used to check how well a forest is progressing towards its goals.

Within the section of Management Direction are management requirements which set the baseline conditions that must be maintained throughout the forest in carrying out the forest plan. They establish environmental quality requirements, mitigation measures, and resource requirements. Management requirements are generally broken down into forest direction and specific management area direction. For any given activity, management requirements may be divided into management activity, general direction statements, and standards and guidelines.

Standards are performance criteria indicating acceptable norms, specifications, or qualities that actions must meet to maintain the minimum considerations for a particular resource. Guidelines assist in determining the course to be taken in any planned activity to accomplish an objective. Standards and guidelines form the basis of "how to" and limit the scope of management activities.

Forest management is concerned with phenomena that occur over specific geographic locations. Questions such as where, when, how much, and what method are the questions typically asked by forest managers. Decisions on these questions are based to a large extent on analyses that consider spatial information often in an ad hoc manner. With the advent of GIS (geographic information systems) and the impending widespread use of these systems by the USFS, previous technical limitations on the spatial analysis of management questions will be removed. However, the ability to address spatial concerns within standards and guidelines will require that standards and guidelines are spatially explicit.

The objectives of this study were twofold: 1. Examine the spatial explicitness of the standards and guidelines of the Land and Resource Management Plan of the Medicine Bow National Forest. 2. Examine the analysis of forest plan standards and guidelines in a GIS using the existing resource database.

METHODS

Study Area and Spatial Data

The study area, chosen on the basis of available spatial and resource data, was the Hayden District on the Medicine Bow National Forest (fig. 1). The Hayden District contains a variety of land types and land uses. Within this district, there are two wilderness areas, on-going timber harvest activities, mining activities, grazing, several campgrounds, and one reservoir. Cover types range from the sagebrush-grasslands at lower elevations to spruce-fir and alpine tundra at higher elevations.

Stand boundaries on quad maps, as of July 1991, had been previously scanned[2] and were imported by quad map

[2] *John Varner, personal communication. Resource Information Specialist, Medicine Bow National Forest, Hayden District.*

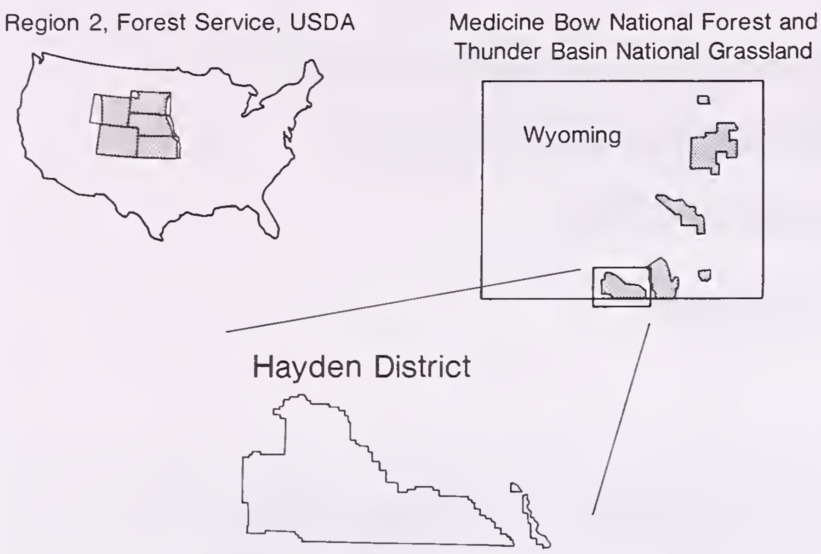

Figure 1.—Medicine Bow National Forest and Hayden Ranger District.

into the PC Arc/Info[3] GIS (ESRI, Inc. 1990) from the Digital Line Graph optional format. All quads were combined to form one district-level coverage.

Resource data was available from the Resource Information System (RIS), a database system standardized within Region 2 of the U.S. Forest Service. Minimum data available on all stands included stand identification number, vegetation type, area, slope, aspect, watershed, management area, and land use class. Additional data available reflected the level of inventory measurements made within the stand. The RIS data were downloaded from the Data General system to a personal computer (PC) and were analyzed in dBase IV (Ashton-Tate, Inc. 1988).

Spatial Content of Standards and Guidelines

Standards and guidelines from the Medicine Bow National Forest and Thunder Basin National Grassland Land and Resource Management Plan (USDA Forest Service, Medicine Bow National Forest and Thunder Basin National Grassland 1985) were used in this study. The Medicine Bow forest plan states management requirements in terms of management activity, general direction statements, and standards and guidelines. We included general direction statements as many of these appeared to have the character of standards and guidelines. Any following reference to standards and guidelines includes general direction statements.

All standards and guidelines were classified into three spatial categories: spatially explicit, ambiguous, and nonspatial. Classification was based on availability of the following spatial information within the standard and guideline: size (e.g., acres, or percent of watershed), number, and location. Standards and guidelines that contained complete spatial information were classified as explicit. Standards and guidelines that contained some spatial information were classified as ambiguous, and standards and guidelines that contained no spatial information were classified as nonspatial.

Spatially explicit standards and guidelines were further grouped into analysis categories based on the method of analysis used within PC Arc/Info. Standards and guidelines pertaining to visuals, line features (i.e., streams, roads, and trails), and point features were not included in the method analysis, nor were they analyzed within PC Arc/Info because electronic data were unavailable for line and point features on the Hayden District.

The following analysis categories were identified:

Stand Level Analysis—Standards and guidelines which apply to specific stands.
Buffer Analysis—Standards and guidelines that apply to certain stands or groups of stands plus additional adjacent area.
Neighbor Analysis — Standards and guidelines that relate one stand to another.
Patton Edge Index—Standards and guidelines that are stated in terms of shape.
Distribution Analysis—Standards and guidelines that are stated in terms of geographic distribution.

Spatial Analysis of Standards and Guidelines

Only one standard and guideline from each analysis category was chosen as an example for analysis in the GIS. The example standard and guideline chosen represents the most complex analysis within each category, and other standards and guidelines within the category could be analyzed similarly with appropriate modifications to the method. Table 1 lists the standard and guideline used as an example for each analysis method. What follows is a description of each analysis method with bold type representing commands within PC Arc/Info. The availability of data within RIS to perform the spatial analyses of the standards and guidelines will be reported in the results section.

Stand Level Analysis

Analysis at the stand level can be performed by querying either within the GIS or the relational database. No standard and guideline was used to demonstrate this analysis.

Buffer Analysis

The standard and guideline used to demonstrate this category defines upland areas as a buffer of riparian areas

[3] *Use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

Table I.—Standards and guidelines used as an example for each analysis.

<table>
<tr><th>Analysis</th><th>General Direction</th><th>Standard and Guideline</th></tr>
<tr><td>Buffer</td><td>2. Identify at the project level, upland areas that are immediately adjacent to Riparian (Prescription 9A) Management Areas. Adjacent upland areas are those portions of a management area which, when subjected to management activities, have a potential for directly affecting the condition of the adjacent Riparian Management Area. The magnitude of effects is dependent upon slope steepness, and the kind, amount, and location of surface and vegetation disturbance within the adjacent upland unit.</td><td>The approximate extent of adjacent upland areas is defined by slope as follows:
<table>
<tr><th>Slope (percent)</th><th>Buffer distance (feet)</th></tr>
<tr><td>0-20</td><td>100</td></tr>
<tr><td>21-30</td><td>180</td></tr>
<tr><td>31-40</td><td>280</td></tr>
<tr><td>41-50</td><td>400</td></tr>
<tr><td>51-60</td><td>520</td></tr>
<tr><td>61-70</td><td>640</td></tr>
<tr><td>71-80</td><td>760</td></tr>
<tr><td>81-90</td><td>880</td></tr>
<tr><td>91-100</td><td>1000</td></tr>
<tr><td>100-150</td><td>1000-1300</td></tr>
</table>
b. Reduce, through designed management practices and appropriate erosion mitigation and vegetation / restoration measures, the project-caused onsite erosion rates (calculated with appropriate Universal Soil Loss Equation methodology) by 75% within the first year after disturbance. Reduce project-caused onsite erosion by 95% within 5 years after initial disturbance.
c. Design continuing mitigation/restoration practices and follow up activities to ensure that 80% original ground cover (vegetation) recovery occurs within 5 years after disturbance (p. III-75 in the forest plan).</td></tr>
<tr><td>Neighbor</td><td>2. Maintain edge contrast of medium or high along at least 30% of the edge next to all created and natural openings, roads, and riparian areas.</td><td>a. Table 2 shows contrast by Age Class (p. III-35 in the forest plan).</td></tr>
<tr><td>Patton Edge Index</td><td>1. Maintain structural diversity of vegetation on units of land 5,000 to 20,000 acres in size, or fourth-order watersheds, that area dominated by forested ecosystems.</td><td>d. In forested areas, create or modify created openings so they have natural appearing shapes. Openings larger than 26 acres should have Patton edge index greater than or equal to 1.4 (p. III-14 in the forest plan).</td></tr>
<tr><td>Distribu-tion</td><td>1. Use both commercial and noncommercial silvicultural practices to accomplish wildlife habitat objectives.</td><td>b. In diversity units dominated by forested ecosystems, maintain a minimum of 40 percent of the diversity unit in deer or elk hiding cover. This hiding cover should be well distributed over the unit. Maintain 20 percent of the diversity unit in thermal cover (winter or spring-summer). Hiding cover can be used to meet thermal cover requirements also, if they indeed coincide biologically (p. III-34 in the forest plan).</td></tr>
</table>

based on slope (table 1), and was an example of a complex buffer.

The analysis involved several steps. First the district stand coverage was **dissolve**d (joins polygons with the same attribute) to form a coverage based on management areas. Riparian areas (management areas 9A) were then **reselect**ed (creates a coverage of polygons meeting the reselection criteria) from the management area coverage. Next a coverage of slopes was **dissolve**d from the stand coverage. The slope coverage was then overlaid (**identity**, overlays two coverages and splits input arcs where overlay polygons intersect and adds polygon attributes to the arc attribute file of the input coverage) onto the riparian area (input) coverage with the **line** option. This allowed the slope attributes of the polygons next to the riparian areas to be added to the line attributes of the riparian areas. A lookup table (used by certain PC Arc/Info commands for parameters) was created with the slope and appropriate buffer distance. The riparian area coverage was then **buffer**ed (creates new polygons at the specified distance parallel to input arcs or

polygons) according to the lookup table and thus a complex buffer was created around riparian areas based on slope.

This coverage was then overlaid (**union**, combines two polygon coverages including attributes) back on the district coverage in order to reassociate attributes which were lost in the buffer operation. Finally, the polygons forming only the riparian buffer were **reselect**ed.

Neighbor Analysis

The standard and guideline used for this analysis defines edge contrast between certain stands (table 1). As an example, we performed this analysis only for riparian areas. The analysis was performed by initially **build**ing (creates or updates attribute tables and defines topology) the coverage for both polygon and line attributes. Once the coverage was built, the database contained information on the riparian area polygons, the lines that formed the edges of the riparian areas, and the vegetation structure and size that bordered the riparian area edges. Contrast was calculated based on table 2. The following operations were then performed within dBase IV.

A typical polygon attribute table (PAT) in dBase IV or PC Arc/Info would contain the following information:

Area (m^2)	Perimeter(m)	Internal ID	User ID	Attributes 1 2...n-1 n
10	40	1	100	
10	50	2	101	
10	55	3	102	
20	80	4	103	

Area and perimeter are the area and perimeter of the polygon identified by the internal ID (identification) and user ID. Attributes one through n would include all of the stand information.

First riparian areas were selected from the PAT using the attribute of management area (i.e., 9A, riparian). A typical arc attribute table (AAT) contained the following information:

From node	To node	Left poly	Right poly	Length (m)	Int. ID	User ID	Attributes 1 2...n-1 n
1	2	2	1	10	1	100	
2	3	3	1	10	2	101	
1	3	1	4	20	3	102	

The left and right polygon are the internal ID's of the polygons that share a given arc.

Next, the internal ID number of the riparian area stands from the PAT was related to the right poly and left poly of the AAT. This step identified the neighbor stands of the riparian area stands, and the arc number (internal ID of the AAT) shared between them.

Table 2.—Edge contrast[1] defined by age class as stated in the standard and guideline of the Medicine Bow National Forest Plan used for the neighbor analysis.

Age Class[2]	OG	M	P	SSS	GF	SHR	GRA
OG	—	L	M	H	H	M	H
M	L	—	M	M	H	M	H
P	M	M	—	M	H	M	H
SSS	H	M	M	—	L	L	L
GF	H	H	H	L	—	M	L
SHR	M	M	M	L	M	—	M
GRA	H	H	H	L	L	M	—

[1]Contrasts: H - High, M - Medium, L - Low

[2]Age Classes: OG - Old Growth, M - Mature, P - Poles, SSS - ShrublSeedling/Sapling, GF - Grass/Forb, SHR - Shrubland, GRA - Grassland

A new file was created by combining the attributes from the PAT and AAT, and new attributes of neighbor and edge contrast were added. This file contained the following information:

Internal ID (PAT)	Neighbor (AAT)	Length(m) with neighbor(AAT)	Edge contrast	Attribute 1...n
1	2	10	L	
1	3	10	M	
1	4	40	H	

This file was then used to relate back to the RIS database. The attribute neighbor was a combination of the attributes left poly and right poly from the AAT, and edge contrast was calculated based on the RIS attributes of vegetation type, size class, and structural stage. Because age class was not available in the RIS database we related similar size class or structural stage to the age class shown in table 2.

Finally, the length of the arcs shared between each riparian area stand and its neighbors was calculated based on edge contrast. For example in this file, riparian area stand 1 has 10 meters of low contrast, 10 meters of medium contrast, and 40 meters of high contrast. The calculation of percent edge contrast was then completed in the database.

Patton Edge Index

The standard and guideline used for this analysis defines edge shape criteria for openings larger than 26 acres (table 1). We performed this analysis for cut areas which are considered openings until the stand fulfills specific criteria for height, stocking, crown cover, or distribution depending on the forest type and management area.

The analysis for this standard and guideline was performed within the database. Openings were first selected,

and then the index was calculated based on the formula (Patton 1975):

$$P.I.=\frac{P}{2\sqrt{(\pi A)}}$$

where
P.I. = Patton Index
P = perimeter
A = area.

The index for a circle is 1, and the value increases as edge complexity increases.

Distribution Analysis

The standard and guideline used for this analysis states how much deer and elk hiding cover must be maintained in watersheds. Hiding cover is defined as vegetation capable of hiding 90% of a standing adult deer or elk from the view of a human at a distance equal to or more than 150 feet. In addition, stands providing hiding cover are required to have a canopy closure greater than 40%. Since this definition was not measurable using the information within the RIS database we developed three definitions based on available data. The first definition assumed that stands with wildlife structural stage of 3c (pole size, crown closure > 70 %), 4c (mature size, crown closure > 70%) or 5 (old growth) met the hiding cover requirement. Because only 59% of all stands had data on structural stage, the second definition assumed stands with size class 8 (pole), or 9 (mature) in addition to stands meeting the structural stage criteria met the hiding cover requirement. The third definition was based on an alternative criterion developed by Smith and Long (1987). They developed a hiding cover model based on a computer simulation and field measurements:

$$Y=100-115.8 * (0.61^{X})$$

where
Y = percent of elk hidden
x = sum of the diameters at breast height(dbh) per acre in inches/1000.

This method determines the percent of an elk hidden at 200 feet or more when only boles provide cover.

Size and shape of hiding cover areas might affect the efficiency of cover. For example long narrow areas less than 150 feet in width might not provide adequate cover. We devised a buffer analysis that eliminated the area within 150 feet from the edge to address this question.

Our analysis was performed in five combinations:
- Wildlife structural stages only with and without a 150 foot buffer.
- Wildlife structural stages and size classes with and without a 150 foot buffer.
- Stand density method based on Smith and Long (1987).

To determine the area of hiding cover per watershed we queried the stands within dBase IV and summed by watershed. The following steps within the GIS were necessary to complete the buffer analysis:

Coverage 1 - **Dissolve** stands together from the District coverage that meet hiding cover requirements.
Coverage 2 - **Reselect** these stands to form a coverage of only polygons meeting hiding cover requirements.
Coverage 3 - **Buffer** by 150 feet the lines forming the polygons of coverage 2.
Coverage 4 -Overlay (**union**) Coverage 2 and Coverage 3 in order to reassociate attributes lost in the buffer operation.
Coverage 5 - **Reselect** polygons from coverage 4 that meet hiding cover, but are outside the buffer zone.

This sequence of steps produces a coverage of areas meeting hiding cover with a zone 150 feet in from their perimeter eliminated. Total area of hiding cover can then be determined again within dBase IV.

The criterion "well-distributed" was not defined within the standard and guideline. We selected two spatial metrics (grid fractal, Moran's I) to explore statistical definitions of well-distributed on the landscape. The grid fractal (Wiens and Milne 1989, Milne 1991) is a measure of the spatial distribution of one defined landscape element (e.g., one vegetation type) on the landscape. Grid fractal values approaching 2 indicate that a landscape element is well dispersed, and values approaching 1 indicate that a landscape element is clumped. Moran's I (Ebdon 1985) quantifies the distribution of all landscape elements (e.g., all vegetation types) on the landscape. Moran's I has limits of 1 and -1 with positive values indicating clumping, and negative values indicating a dispersed distribution.

PC Arc/Info does not provide a utility for quantifying either of these spatial metrics, but it does have utilities for exporting data in 13 different formats. The analysis of distribution was calculated by exporting the coverage of stands meeting hiding cover to a raster format with cell size of one acre. The grid fractal was calculated using the Rocky Mountain Spatial Analysis Package (RMSAP[4]). Moran's I was calculated in the raster GIS IDRISI (Eastman 1992) using cells that were joined horizontally or vertically, but not diagonally.

RESULTS

Standard and Guideline Analysis

Table 3 shows that most of the standards and guidelines (including general direction statements) were not spatially explicit (65%), while 19% were explicit, and 16% were

[4] *Curt Flather, Research Wildlife Biologist; Robert Macneal, Computer Specialist, in preparation. Rocky Mountain Forest and Range Experiment Station, 3825 E. Mulberry, Fort Collins, CO, 80524.*

ambiguous. The classification of the explicit standards and guidelines into analysis categories was as follows:

Analysis category	Number	Percent
Stand	43	34.4
Buffer	31	24.8
Neighbor	9	7.2
Patton Edge Index	2	1.6
Distribution	3	2.4
Categories not analyzed[5]		
Line Features (Roads, Trails, Streams)	22	17.6
Point Features	15	12.0

About one third could be analyzed at the stand level, and 25% required a buffer analysis. The other analysis categories accounted for 11%, while explicit standards and guidelines relating to line and point features comprised a substantial portion (30%).

Table 3.—Spatial explicitness of standards and guidelines of the Medicine Bow National Forest Land and Resource Management Plan (values in parentheses are percentage).

	Total		General Direction		Standards & Guidelines	
Number	658		333	(50.6)	325	(49.4)
Explicit	125	(19.0)	28	(8.4)	97	(29.8)
Ambiguous	107	(16.3)	31	(9.3)	76	(23.4)
Nonspatial	426	(64.7)	274	(82.3)	152	(46.8)

Spatial Analysis

Buffer Analysis

A list of coverages created, process times, and storage requirements for this, and subsequent analyses are provided in Appendix A. Figure 2 shows the result of the complex buffer analysis for several riparian areas. This method could be applied to either line or polygon attributes, and could be used with any combination of attributes available in the database. In general this analysis was useful although some problems were created by the method used.

In order to perform a complex buffer operation the lines defining the riparian areas had to be buffered. This operation created areas classified as being outside the buffer that are actually within the riparian area (false islands, fig. 2). Secondly, in some cases where the slope on one side of the riparian area was much greater than on the other side and the riparian area was narrow, the buffer from

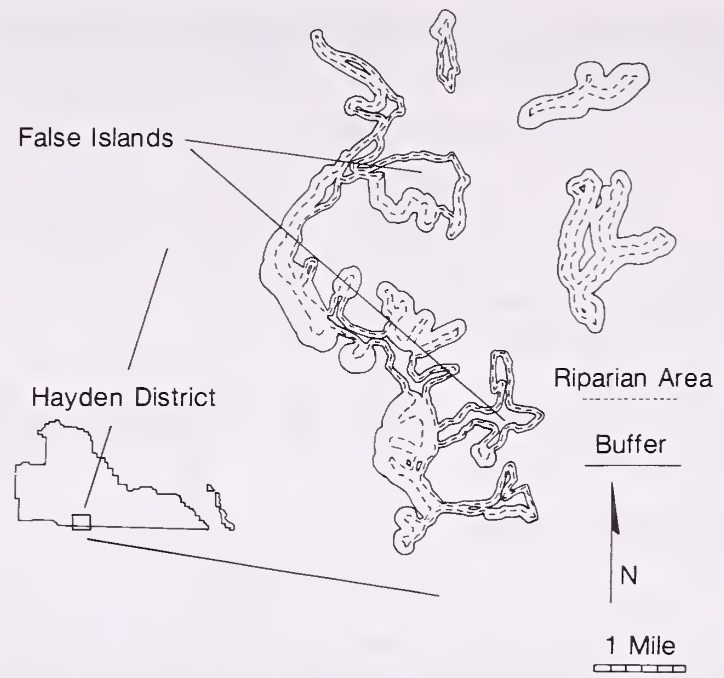

Figure 2.—Selected riparian areas with buffers defining upland areas.

the steep side would actually extend past the true buffer distance on the gentle side. The false islands can be removed by reselecting areas inside the buffer and outside of the riparian area, but the overlap from one side to the other would have to be corrected by hand.

Data from the RIS used in this analysis included the management area code and the slope of the stand. All stands had the management area information, however only 98% of the stands had slope information.

Neighbor Analysis

Table 4 shows the result of the edge contrast analysis for several stands. Figure 3 shows a map of these stands and the location of the various edge contrasts. The neighbor analysis could be completed based on any combination of attributes available in the database.

Data from the RIS used in this analysis included vegetation or type (98% of stands had data), size class (76% of stands had data), and structural stage (59% of stands had data). Lack of data for some stands resulted in unknown edge contrasts.

Patton Edge Index

The results of the Patton edge index analysis were as follows:

Size of cut area	All cut stands (all numbers are percent of stands)	PI < 1.4	PI >= 1.4
Area ≥ 26 acres	16.2	31.7	68.3
Area < 26 acres	83.8	70.7	29.3

Approximately 32% of the cut areas greater than 26 acres do not meet the standard and guideline. Figure 4 shows the Patton edge index for several stands.

[5] *Electronic data were not available for these features; no analysis methods were developed.*

Table 4.—Edge Contrast for selected riparian area stands (see fig. 3 for a map of these stands).

Number	Contrast	Percent of Perimeter
5669	low	50.4
5669	medium	28.2
5669	high	21.4
6188	unknown	14.9
6188	low	85.1
6250	unknown	4.1
6250	low	22.2
6250	medium	73.5
6382	unknown	9.5
6382	low	45.6
6382	medium	25.5
6382	high	19.4
6736	unknown	0.5
6736	low	41.0
6736	medium	54.7
6736	high	3.9
6749	unknown	4.5
6749	low	75.1
6749	medium	16.8
6749	high	3.6
7401	unknown	4.3
7401	low	12.6
7401	medium	74.3
7401	high	8.9

Data from the RIS used in this analysis included vegetation or type (98% of stands had data), date of origin (51% of stands had data), and height (41% of stands had data).

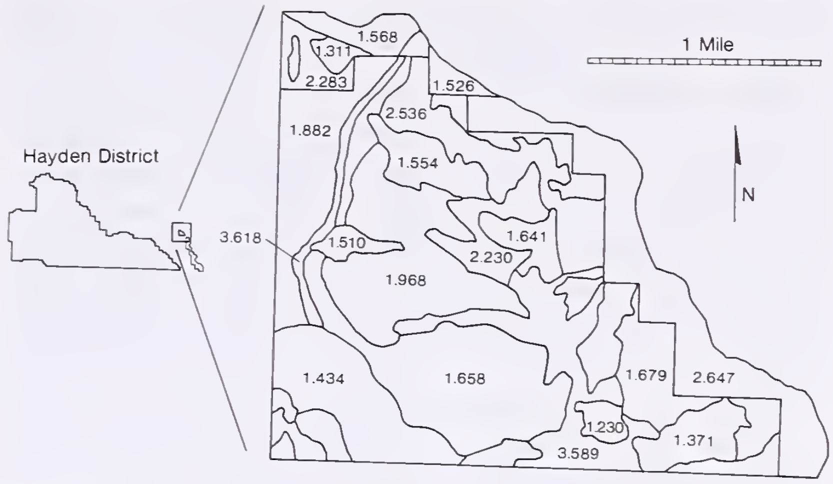

Figure 4.—Patton edge index for selected stands.

Distribution Analysis

The results of the hiding cover and distribution analysis for watershed 93A01 were as follows:

Cover method	Percent of watershed with data available	Percent of watershed meeting cover	Grid fractal	Moran's I
Size class	100	66.3	1.878	0.7504
Size class(B)	100	51.0	1.820	0.8769
Str. stage	49.8	34.7	1.661	0.7619
Str. stage(B)	49.8	23.6	1.582	0.8523
Stand density	32.6	3.3	1.235	0.8439

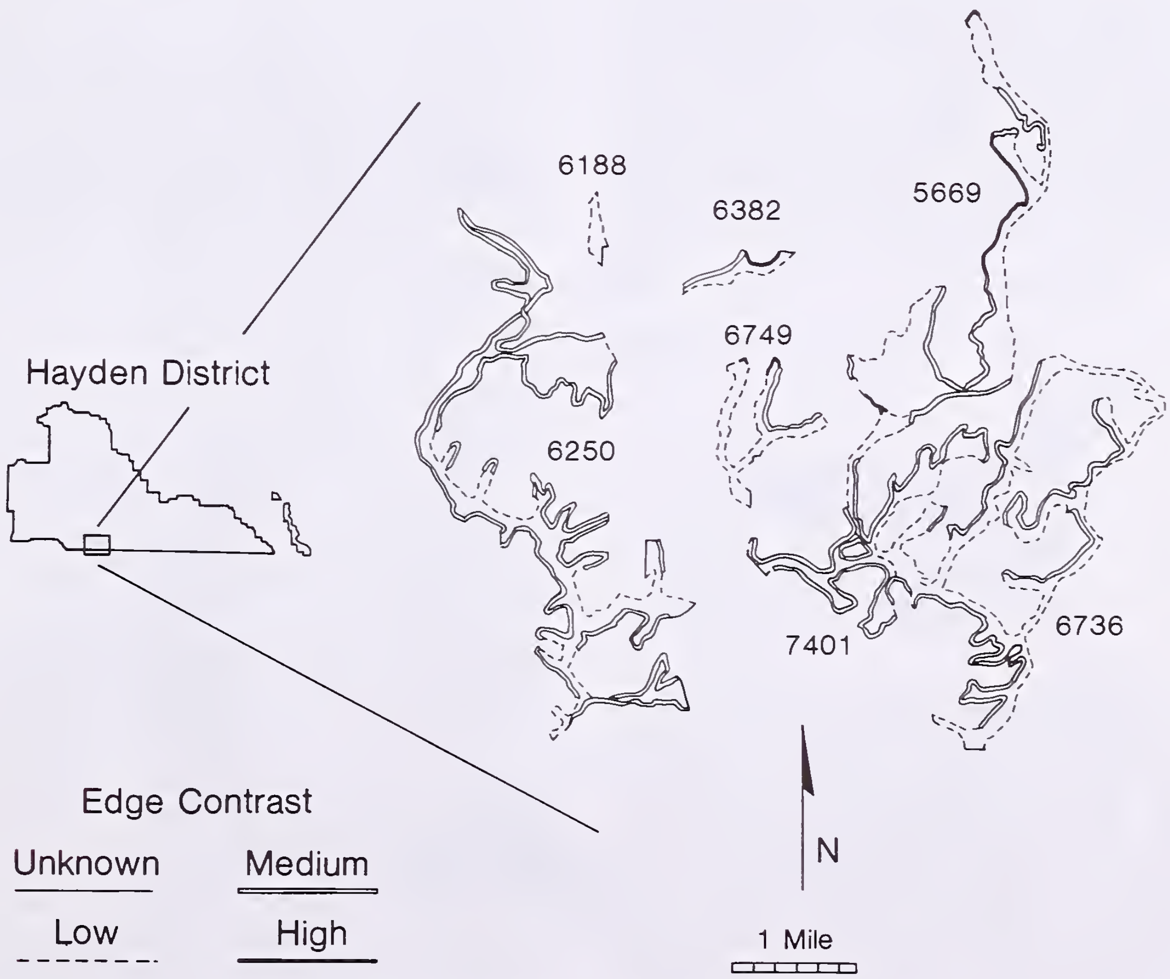

Figure 3.—Riparian edge contrast for selected stands.

A "(B)" in the cover method column indicates a buffer operation was performed.

Watershed 93A01 only met the standard and guideline hiding cover requirement (minimum of 40% of the watershed area) for the size class definition. The buffer reduced the amount of hiding cover by 15.3% for the size class definition and 11.1% for the structural stage definition. For all watersheds and both definitions the buffer reduced the amount of hiding cover an average of 12.6% (range 1.7% - 31.0%).

The percent of watersheds subject to this standard and guideline that met hiding cover requirements for the various methods was as follows:

Cover Method	Percent of watersheds meeting 40% hiding cover criterion
Size class	66.7
Size class(B)	33.3
Structural stage	44.4
Structural stage(B)	14.8
Stand density	0.0

A "(B)" in the cover method column indicates a buffer operation was performed.

Figure 5 shows the grid fractal and Moran's I value for hiding cover (structural stage definition) distribution plotted against the percent area meeting hiding cover for each watershed. In general, the grid fractal indicated hiding cover was dispersed, while Moran's I indicated clumped distributions. In addition, the grid fractal tended to increase as the amount of cover in the watershed increased, whereas no pattern was seen for Moran's I.

Figure 6 compares two watersheds that are similar in area, hiding cover percent, and Moran's I; they differ greatly, however, in their grid fractal value (watershed

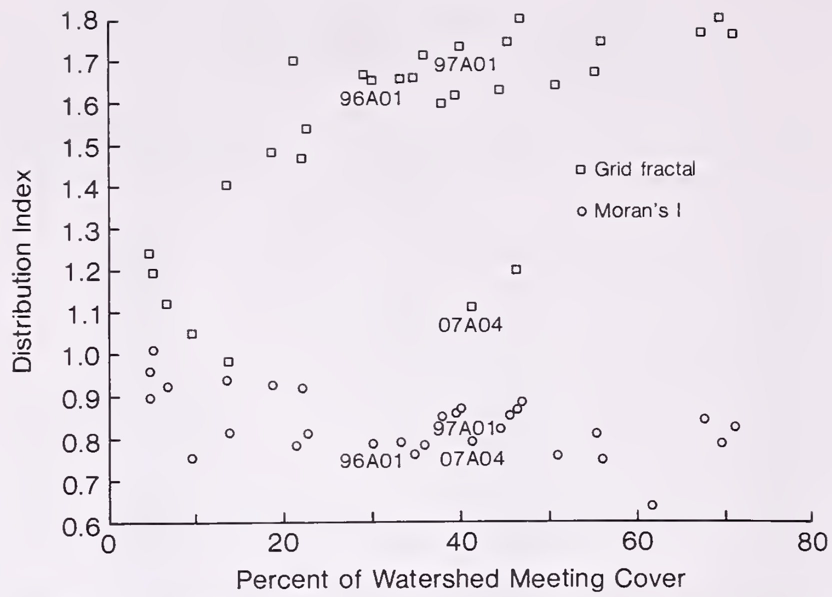

Figure 5.—Comparison of hiding cover (structural stage definition) distribution indices in relation to percent area per watershed meeting hiding cover requirements.

07A04 = 1.110, watershed 97A01 = 1.735). The inner box overlaying the watersheds shows the area used to calculate the grid fractal for the RMSAP program.

Data from the RIS used in this analysis included vegetation or type (98% of stands had data), size class (76% of stands had data), structural stage (59% of stands had data), basal area (38% of stands had data), and dbh (38% of stands had data).

DISCUSSION

Standards and Guidelines

The Medicine Bow National Forest Land and Resource Management Plan states management requirements in terms of management activity, general direction statements,

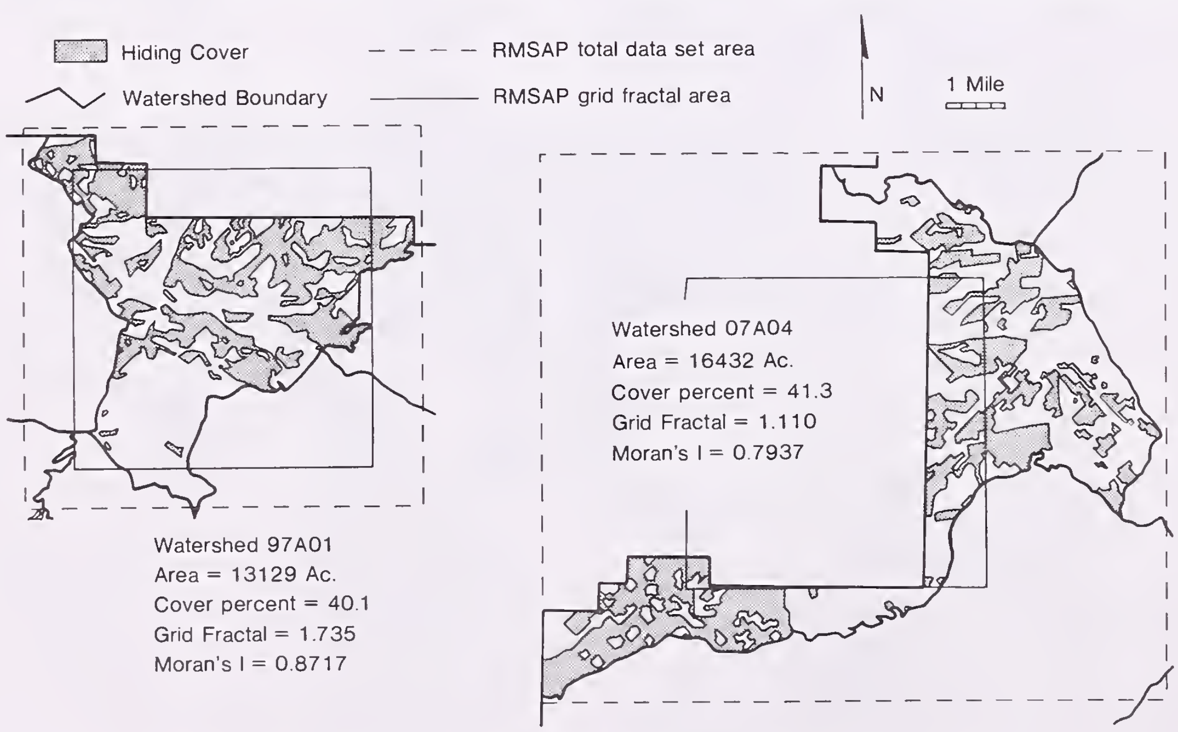

Figure 6.—Hiding cover distribution for watersheds 07A04 and 97A01.

and standards and guidelines. While general direction statements would not be expected to be spatially explicit we included them in our analysis and found that 18% of these statements were either spatially explicit or ambiguous. Therefore, the following discussion of standards and guidelines includes general direction statements.

Most standards and guidelines were not spatially explicit (65%), and of the remaining standards and guidelines, about half were explicit and half were ambiguous. Standards and guidelines are performance criteria indicating acceptable norms regarding the management of a resource. Such criteria may not need to be spatially explicit as in the following guideline: “Conduct habitat improvement projects jointly or cooperatively funded with the states.” This guideline and similar guidelines do not require a spatial analysis and thus do not need spatial criteria in their definition. Within the nonspatial category, there were other standards and guidelines focused on specific management actions that were not defined in a spatial manner. The following information is necessary for a standard and guideline to be spatially explicit:

Activity - The exact nature of the management or mitigation should be stated.
Location - Needs to be precise and measurable.
Number or Size - Should be measurable and not relative.
Definition - Should be measurable within the available data.

Guidelines identified as ambiguous lacked information from at least one of these areas which prevented spatial analysis.

An additional information element is the temporal nature of the standard and guideline. Some standards and guidelines refer to actions or criteria that vary over time, or require action at specific times. Such information should be specifically included within the definition. At this time, however, temporal analysis with a GIS is limited.

In general, spatially explicit standards and guidelines should be written so they can be monitored in the field, and also within a GIS. In many cases assumptions were necessary to spatially analyze the standards and guidelines within a GIS. For example, the hiding cover standard and guideline states that fourth order watersheds dominated by forest must meet a certain cover percent while other watersheds must meet different criteria. We assumed that “units dominated by forest” were greater than 50 percent forested.

The hiding cover standards and guidelines also state that the cover should be well distributed. While intuitively one may know what this means, no definition was given in the plan. We described the distribution of cover using a grid fractal and Moran’s I. While these measurements provide an objective measure of distribution, they do not answer the question “What is well distributed?” Distribution guidelines could be stated in terms of a uniform or clumped distribution as these are statistical qualities that could be measured, or distribution could be described according to specific resource needs. In the case of elk and deer hiding cover, distribution could be stated in terms of distance (minimum and/or maximum) between patches of hiding cover.

Standards and guidelines should also have some ecological reality. When we determined the amount of hiding cover per watershed using the stand density technique (Smith and Long 1987) no watersheds met the 40% minimum. The most cover any watershed had was 21%. One way to determine what is realistic might be to calculate how much hiding cover exists naturally and how it is distributed in an undisturbed watershed. In addition, knowledge of what elk truly need in cover, or how elk use the local habitat to obtain cover would be important. Different scales of analysis may be important in determining what is realistic. For example the size and distribution of old growth might be more important at the district or forest level than at the watershed level. In addition, standards and guidelines developed at the regional level may not be as ecologically realistic as those developed at the forest level due to local variation in ecosystems. This could have significant implications for forests in Region 2 where standards and guidelines were written as a mosaic of the region.

Resource Information

Data Quantity

Data quantity refers to the completeness of inventoried data. While the RIS database has many fields of data covering a wide range of resource needs, much of this information is not available for all stands. Generally the amount of data available for a given stand is determined by the survey level. For the Hayden District the percent of stands at the various survey levels are:

Survey level	Percent of stands
None	24
Photo	18
Walk Through	21
Plots - Quick	5
Plots - Low Reliability	19
Plots - High Reliability	14

In analyzing hiding cover using the stand density technique only 38% of all stands (stands with plot data) had the information needed. The data availability for basal area and dbh for individual watersheds ranged from 10% to 85% of the area of the watershed (not percent of stands). One way to deal with data quantity might be to develop methods for describing compliance with standards and guidelines based on the survey level of the stand. For a given standard and guideline there might be three different

methods for monitoring compliance. While this could complicate the process, at least some measurement could be made for all stands, and assumptions regarding the analysis would be standardized.

Data Availability

Data availability refers to data that is used in definitions in standards and guidelines, but is not an inventoried item. Some standards and guidelines utilize information that is not available in RIS. For example, the standard and guideline for cover defines hiding cover as vegetation that can hide 90% of an elk at 150 feet. There is no way to directly measure this in the RIS database. We have seen that only 38% of stands have sufficient tree plot data to use the method developed by Smith and Long (1987). Smith and Long (1987) also developed a measure for hiding cover when lodgepole pine crowns contribute to cover (base of crown less than 3 feet). However, RIS and current surveys do not provide information on the base of tree crowns.

Other sub-stand level standards and guidelines (i.e., vertical diversity, nest sites) can not be analyzed using the RIS database because data is not available. In addition, sub-stand level attributes measured and averaged for the entire stand would not be spatially explicit. For example, identifying only the number of nest sites within a stand would not provide explicit spatial information to analyze nest site buffers. Analysis of nest site attributes would require a geographic specificity greater than that provided by the stand boundaries. There is a need to either define standards and guidelines in terms of data that is available or to acquire the necessary data when it is not available.

Data Quality

While our study made no attempt to analyze the quality of RIS data, we did encounter obvious errors. For example, we discovered several stands where the structural stage did not match the size class (e.g., structural stage—mature, size class—seedling/sapling). The continued use of GIS systems may cause people to view these maps and associated data as being more accurate than they are (Bailey 1988). In light of this misperception it will become more important to document the quality of data, and to increase its quality.

Spatial Analysis

While the GIS is useful for analysis, we found in many cases that using PC Arc/Info to generate spatial attributes and completing the analysis elsewhere was sometimes more effective. For the distribution analysis we exported data to a raster format, and performed an analysis in a raster GIS (IDRISI) and the RMSAP program. In the case of the neighbor analysis and the Patton edge index analysis, we performed the majority of the analysis in the database (dBase IV) once spatial attributes had been created in PC Arc/Info. The analyses often involved multiple steps that were not readily apparent. These steps typically involved multiple overlays and reselections to produce the desired result. For example, the hiding cover buffer analysis required five different operations within the GIS. There is a need to develop and refine spatial analysis procedures within GIS systems.

Analyzing the distribution of hiding cover areas presented some interesting problems. Watersheds 07A04 and 97A01 were similar in area, hiding cover (structural stage definition) percent, and Moran's I; however they differed greatly in their grid fractal value (watershed 07A04 = 1.110, watershed 97A01 = 1.735, fig. 6). This may have been due to the way the RMSAP program determines the largest window used in calculating the grid fractal. The largest window that can be fit over the data set is based on the extant (maximum x and y) and the cell size. Because of the odd shape of watershed 07A04 most of it is located in the east side of the area considered in the calculation of the grid fractal. On the other hand, watershed 97A01 almost completely fills the area considered in the calculation of its grid fractal. Odd-shaped watersheds such as 07A04 are not easily analyzed using the grid fractal.

In general, the values for Moran's I showed that hiding cover was significantly clumped while the grid fractal indicated dispersion of hiding cover. This was probably due to the grid cell size (1 acre) used to calculate Moran's I. We might expect this because areas of hiding cover are much larger than 1 acre. Calculating Moran's I for 1-acre cells measures the spatial distribution of the cells and not the much larger hiding cover patches. For watershed 96A01 we calculated Moran's I using contraction factors:

Contraction factor	Moran's I
0	0.7888
2	0.6128
4	0.4677
8	0.3423
16	-0.0004

Contraction factors cause the Moran's I analysis to compare a cell to more distant cells. For example, a contraction factor of two compares the given cell to cells two cells distant. As you increase the contraction factor you compare the given cell to more remote cells. As we increased the contraction factor Moran's I decreased until it reached -0.0004 indicating random distribution for a contraction factor of 16. The grid fractal for this watershed was 1.655 indicating dispersion. Increasing cell size would also have an effect on the value of Moran's I. For both methods we used to describe distribution, assumptions played an important role. Assuming a cell size of 1 acre for Moran's I had

a significant effect on the calculation. In the grid analysis, the calculation is based on a square-shaped area, thus the more a watershed varies in shape from a square the more it affects the result.

For this study, we focused on the existing standards and guidelines and the available resource data. Using the stand boundaries as a picture of the landscape restricts the analysis to the scale of the stand boundaries. This requires that all questions be stated such that an analysis of stand boundaries could answer them. Sometimes stand boundaries reflect naturally occurring phenomena, such as the riparian zones. However, other phenomena may not be adequately captured, such as the size of naturally occurring fires, insect patches, soil descriptions, and wildlife migrations. Potentially, the advent of GIS at the district level could expand analyses, such that this additional spatial data could be overlaid on the stand boundary maps. While this combination adds new analysis possibilities, additional questions arise concerning the registration of the spatial data, and data quality.

CONCLUSION

Certain standards and guidelines are truly nonspatial in nature and only provide nonspatial guidance. However, there is a real need for forest plan standards and guidelines dealing with spatial information to be explicit in terms of size, number, and location for a given management activity. In addition, some spatial standards and guidelines must also be explicit in terms of distribution on the landscape, and/or time frequency. Other criteria for many standards and guidelines include ecological realism, and use of precise definitions that are stated in terms of the existing resource database.

If standards and guidelines are to be implemented across an area (such as a group of stands or a watershed), accurate information for that entire area should be available. Quality spatial analyses (for standards and guidelines, decision support, or other purposes) also require accurate information for the entire area being analyzed. There is a need to design data acquisition plans and databases in order to provide the necessary information for these analyses.

In conclusion, quality spatial analysis requires that:

1. Managers know what information they need to make proper decisions and communicate their needs well (e.g., standards and guidelines).
2. Accurate and complete information is available (resource database).
3. Analysts have access to the necessary tools to complete the analysis (GIS and other analysis tools). If resource managers are to get the maximum utility from geographic information systems, then we need to begin thinking in spatial terms regarding all aspects of management.

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Appendix A.

Files Created in Spatial Analyses

This appendix lists the files created in analyses, times for processing, number of polygons and arcs in coverages and file sizes. Processing times could be reduced using disk cache systems. However, it should be noted that our disk cache caused unexpected system halts in PC Arc/Info. System used was a CSI 486-33 with 64K internal cache, 8MB RAM, and 667 MB SCSI disk drive.

Coverage	Description	Time (hours:minutes)	# Polys	# Arcs	Kilobytes
General					
Import data, correct errors		2 weeks			
HAYDEN1	Mapjoined Quads	2:00			
HAYDEN3	Slivers removed with Eliminate	:06	8863	24871	——
HAYDEN4	Quad Boundaries Dissolved	:20	8127	23173	——
HAYDEN9	Updated District Coverage	3 days	8130	23283	8138
Buffer Analysis					
SLOPE	Dissolved from HAYDEN9	:55	4267	11469	2931
MGTAREA	Dissolved from HAYDEN9	:47	1086	2496	964
RIPAREA	Reselected from MGTAREA	:01	118	380	159
RIPAREA1	Identity RIPAREA/SLOPE	:55	0	767	226
RIPBUFF	Buffered RIPAREA1 w/LUT	:28	355	364	298
RIPBUF1	Union RIPAREA RIPBUFF	:10	475	476	450
RIPBUF5	Reselected RIPBUF1	:01	126	118	186
				total	**5214**
Neighbor Analysis and Patton Edge Index					
HAYDEN9	Build for Line attributes	:06	8130	23283	10000
Distribution Analysis					
HIDECOV1	Dissolve HAYDEN9	:50	2029	3991	1578
HIDECOV2	Reselect HIDECOV1	:09	1224	2810	1112
HIDECOV3	Dissolved HIDECOV1	:10	1550	2698	1327
HIDECOV4	Reselect HIDECOV3	:09	1312	2315	1199
HIDEBUF1	Buffer HIDECOV2	6:45	2644	2927	2863
HIDEBUF2	Buffer HIDECOV4	7:30	3037	3345	3264
HIDEBUF3	Union HIDECOV2 HIDEBUF1	3:20	3912	6465	4405
HIDEBUF4	Union HIDECOV3 HIDEBUF2	4:10	5245	9020	5358
HCOVER1	Reselect HIDEBUF3	:05	1448	1869	1623
HCOVER2	Reselect HIDEBUF4	:05	1571	2379	1868
WATER1	Dissolved from HAYDEN9	:20	32	115	118
WSxx	HAYDEN9 split by WATER1 (watershed coverages)	2:00	——	——	6300
ASCII files for grid analysis and Moran's I		:10			7700
				total	**38597**

Gokee, Terry L.; Joyce, Linda A. 1992. Analysis of standards and guidelines in a geographic information system using existing resource data. Res. Pap. RM-304. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

Using data from the Hayden Ranger District, Medicine Bow National Forest, methods for analyzing spatially explicit standards and guidelines within a geographic information system were developed. Only 19% of the standards and guidelines were described in a spatially explicit manner. Methods were developed for buffer analyses, neighbor analyses, Patton edge index analyses, and geographic distribution analyses. The low number of spatially explicit standards and guidelines indicates there is a need to begin thinking in spatial terms in resource management.

Keywords: Forest plan standards and guidelines, geographic information systems

U.S. Department of Agriculture
Forest Service

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